

## **Functional Data Analysis of Spaceflight-Induced Changes in Coordination and Phase in Head Pitch Acceleration during Treadmill Walking**

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Astronauts returning from spaceflight experience neurovestibular disturbances during head movements and attempt to mitigate them by limiting head motion. Analyses to date of the head movements made during walking have concentrated on amplitude and variability measures extracted from ensemble averages of individual gait cycles. Phase shifts within each gait cycle can be determined by functional data analysis through the computation of time-warping functions. Large, localized variations in the timing of peaks in head kinematics may indicate changes in coordination. The purpose of this study was to determine timing changes in head pitch acceleration of astronauts during treadmill walking before and after flight. Six astronauts (5M/1F; age =  $43.5 \pm 6.4$ yr) participated in the study. Subjects walked at 1.8 m/sec (4 mph) on a motorized treadmill while reading optotypes displayed on a computer screen 4 m in front of their eyes. Three-dimensional motion of the subject's head was recorded with an Inertial Measurement Unit (IMU) device. Data were recorded twice before flight and four times after landing. The head pitch acceleration was calculated by taking the time derivative of the pitch velocity data from the IMU. Data for each session with each subject were time-normalized into gait cycles, then registered to align significant features and create a mean curve. The mean curves of each postflight session for each subject were re-registered based on their preflight mean curve to create time-warping functions. The root mean squares (RMS) of these warping functions were calculated to assess the deviation of head pitch acceleration mean curves in each postflight session from the preflight mean curve. After landing, most crewmembers exhibited localized shifts within their head pitch acceleration regimes, with the greatest deviations in RMS occurring on landing day or 1 day after landing. These results show that the alteration of head pitch coordination due to spaceflight may be assessed using an analysis of time-warping functions.